# PROTECTIVE HEADGUARD

**[0001]** This application claims the benefit of United States Provisional Application No. 60/445,153, filed February 5, 2003.

## FIELD OF INVENTION

**[0002]** The present invention generally relates to protective headgear. Specifically, it relates to protective headgear intended to reduce angular acceleration of the human brain caused by an impact to the protective headgear.

## BACKGROUND OF THE INVENTION

**[0003]** The prior art contains many examples of protective headgear or helmets intended to attenuate shock directed at the head. Protective headgear is used in many human sports and activities such as American football, Australian rules football, martial arts, equestrian sports, wrestling, cycling, lacrosse, baseball, hockey, inline skating, skateboarding, skiing, snowboarding, soccer, rock climbing and whitewater canoeing or kayaking. Protective headgear is also used in work activities such as construction, the military and firefighting.

**[0004]** Headgear is generally designed to protect the head from at least one of three kinds of impact. First, protective headgear may be intended to protect the wearer from penetrating objects. This is particularly true with military headgear. Second, headgear may be designed to protect the wearer from contact loading, *i.e.*, loading at the point of impact. An injury from contact loading might be a skull fracture.

**[0005]** Third, headgear may be intended to protect the wearer from inertial loading, *i.e.*, acceleration or deceleration of the brain from an impact to the head. There are two kinds of head acceleration that can occur in an impact. Acceleration of the head in a plane directed at the head's center of gravity is called linear or translational acceleration. Acceleration along an arc is called angular or rotational acceleration.

**[0006]** Given the structure of the brain and skull, and the way they respond to forces, most biomechanical and medical research indicates that angular, rather than linear, acceleration causes relatively greater damage to the brain. See, *e.g.*, Holbourn, A.H.S., "Mechanics of Head Injuries," ***The Lancet***, 2, 438-441 (1943); Ommaya, A.K. and Gennarelli, T.A., "Cerebral Concussion and Traumatic Unconsciousness: Correlations of Experimental and Clinical Observations on Blunt Head Injuries," ***Brain***, 97, 633-654 (1974). It has been demonstrated that padding can reduce angular acceleration of the head. See, Sances, A. and Kumaresan, S., "Padding in Child Restraint and Roll Bar Systems for Head Injury Reduction," published at http://www.ataassociates .com/sances/index.html. However, the prior art contains few examples of padding or shock attenuation systems intended to manage changes in angular acceleration.

**[0007]** This lack of systems intended to manage changes in angular acceleration is significant. In many instances the materials or systems that best manage or modulate linear forces may not best manage or modulate angular forces. Moreover, since the head of a wearer of protective headgear may be subjected to both linear and angular acceleration in response to an impact, it is important that devices be developed that protect wearers from both linear and angular impact forces.

**[0008]** The few examples of materials and systems that do seek to protect wearers from linear and angular forces can be grouped as follows. The first group of protective headgear devices includes those devices wherein the padding is formed or constructed in a way to absorb angular forces. Such technologies take a material with certain properties and improve its ability to respond to shearing forces by shaping or forming the material in a certain way.

[0009] For example, United States Patent No. 6,397,399 to Lampe et al. fits within this first category. The Lampe (399) patent discloses a headguard for use in sports such as soccer. The headguard has padding consisting of pillows or "nubbins" covering at least a portion of the forehead of the wearer. When angular forces are directed at the surface of the headguard, the nubbins bend allowing the exterior surface of the headguard to shift in the direction of the angular force. This shifting may help modulate the angular acceleration of the head.

[0010] There may be practical limitations on the height of the pillows or nubbins for protective headgear. Given this, they may be best suited for applications where the angular forces are limited.

[0011] Another group of technologies includes devices wherein a material of a lower shear modulus (*i.e.*, an elastic body) is positioned in headgear between a shell (*i.e.*, a rigid outer layer) and a liner. This elastic body lowers the overall shear modulus of the protective layers. United States Patent Application, Pub. No. US 2001/0032351 to Nakayama et al., is an example of this. The Nakayama Application discloses a helmet with a rigid shell and inner liner. An elastic body, such as a gel, is positioned between the shell and the inner liner and "stuck" to the interior side of the shell and the exterior side of the inner liner. The elastic body would permit the shell to shift in relation to the liner when angular forces are directed at the helmeted head. To permit the shell to shift in all directions, the Nakayama patent discloses a spherical shaped shell and liner.

[0012] The device disclosed in the Nakayama Application has limitations. First, with a rigid shell or a rigid liner, rotation of that shell in relation to the liner can only effectively occur if both the shell and the liner are substantially spherical in shape. The head, however, is not spherically shaped. To create an inner liner with a spherically shaped outer surface would require adding substantial bulk to the liner. For many applications, therefore, the device contemplated by the Nakayama Application may be impractical. Second, rotation will be limited by the elasticity of the elastic body. Third, the resistance to shearing may increase as the elastic body is stretched. While this may be suitable for some applications, in others it may be desirable to have a more constant rate of resistance.

[0013] A final group of headgear intended to modulate angular acceleration of the head includes devices where the protective headgear as a unit can move on the surface of the head to attenuate angular forces. United States Patent No. 6,247,181 to Hirsch et al. discloses a bandana type headband with foam encased by fabric. The non-rigidity of the device itself allows the inner surface of the headgear to move across the head in response to angular forces.

[0014] The capability of headgear to move in relation to the surface of the head is not unique to the device disclosed in the Hirsch Patent. Any protective headgear that fits less snugly or that has the capacity to deform and shift as a unit in response to an impact could perform the same function. However, the capacity for such a device to modulate angular forces may be difficult to predict or control since head shapes, moisture on the surface of the head, and hair may all affect this capacity.

[0015] There is a need therefore for a device that can respond to and help protect the head from relatively high levels of angular forces; that can be incorporated into a piece of headgear of less bulk and weight; and that could consistently provide protection to the head from angular forces.

## SUMMARY OF THE INVENTION

[0016] Generally, the present invention relates to improvements to a headguard for athletes. A first aspect of the invention is a headguard comprising overlapped inner and outer layers attached so as to permit frictional sliding of at least one area of the outer layer over the inner layer.

[0017] A second aspect of the invention is a headguard comprising overlapped inner, intermediate and outer layers attached so as to permit frictional sliding of at least one area of the outer layer over the intermediate layer.

[0018] A third embodiment of the invention is a headguard comprising (i) overlapped inner and outer layers, and (ii) a flowable material intermediate the layers, wherein (iii) the inner and outer layers are attached so as to permit sliding of at least one area of the outer layer relative to the inner layer subject to drag exerted by the flowable material.

[0019] Objects and advantages of this invention include:

[0020] Protective headgear that reduces or modulates angular acceleration of the head by reducing or modulating rotational forces acting upon the head.

[0021] Protective headgear that can consistently reduce or modulate relatively high levels of rotational forces acting upon the head.

[0022] Protective headgear that not only reduces or modulates rotational forces but also modulates linear forces.

[0023] Protective headgear that is relatively lightweight.

[0024] Protective headgear that reduces or modulates rotational forces with at least two layers that at least at certain locations are not connected and that can slide in relation to one another at or near those unconnected locations.

[0025] Protective headgear where the ease with which the two layers can slide in relation to one another is regulated at the interface of those two layers. Examples of such regulating materials include:

[0026] Introducing fluids of either lower or higher viscosity between the layers to adjust the ease with which the layers can slide in relation to each other.

[0027] Introducing a gas between the layers to adjust the ease with which the layers can slide in relation to each other.

[0028] Inserting particles between the layers to adjust the ease with which the layers can slide in relation to each other.

[0029] Providing the layers with interfacing surfaces of greater or lesser smoothness to adjust the ease with which the layers can slide in relation to each other.

[0030] Inserting a third layer of material, such as a film interposed between the layers, to adjust the ease with which the layers can slide in relation to each other.

[0031] Modifying the texture of the interfacing surfaces of the outer and inner layers to adjust the ease with which the layers can slide in relation to each other.

[0032] Affixing rougher or smoother materials to one or both of the interfacing surfaces to adjust the ease with which the layers can slide in relation to each other.

[0033] Protective headgear in which the interfacing surfaces of the inner and outer layers may be but do not have to be spherical.

[0034] Protective headgear in which the sliding of the layers as the result of an impact permanently deforms the protective headgear.

[0035] Protective headgear in which the sliding of the layers as the result of an impact does not permanently deform the protective headgear. Examples of means for achieving such a recoverable repositioning of the layers include:

[0036] Construction of one or both layers from an elastic material.

[0037] Use of elasticity anchors (where the layers are connected).

[0038] Manual realignment of the layers to their original orientation.

## Brief Description of the Drawings

[0039] The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings.

[0040] FIG. 1 is a side elevation view of a first embodiment of the external configuration of the headgear worn by a wearer.

[0041] FIG. 2 is a side elevation view of a second embodiment of the external configuration of the headgear worn by a wearer.

[0042] FIG. 3 is a cross-sectional side view of one configuration of the layers used to form the headgear.

[0043] FIG. 4 is a cross-sectional side view of headgear having the external configuration of FIG. 1 with a deformable outer layer after localized deformation of a portion of the outer layer caused by application of an angular force upon the headgear.

[0044] FIG. 5 is a cross-sectional side view of the headgear having the external configuration of FIG. 1 with a rigid outer layer after sliding of the outer layer relative to the inner layer caused by application of an angular force upon the headgear.

**[0045]** FIG. 6 is a cross-sectional side view of the headgear having the external configuration of FIG. 1 with an interface layer between the inner and outer layers after deformation of the outer layer relative to the inner layer caused by application of an angular force upon the headgear.

**[0046]** FIG. 7 is a side elevation view of the headgear having the external configuration of FIG. 2 with a flexible outer layer after sliding of the front portion of the outer layer relative to the inner layer caused by application of an angular force upon the headgear.

**[0047]** FIG. 8 is a side elevation view of the headgear having the external configuration of FIG. 2 with a rigid outer layer after sliding of the outer layer relative to the inner layer caused by application of an angular force upon the headgear.

**[0048]** FIG. 9 is an exploded cross-sectional view of an embodiment of the inner and outer layers of the headgear with nodules on the interfacing surfaces of the layers.

**[0049]** FIG. 10 is a perspective view of the inner layer shown in FIG. 9.

**[0050]** FIG. 11 is an exploded cross-sectional view of another embodiment of the inner and outer layers of the headgear with "hair-like" projections on the interfacing surfaces of the layers.

**[0051]** FIG. 12 is a perspective view of the inner layer shown in FIG. 11.

**[0052]** FIG. 13 is an exploded cross-sectional view of yet another embodiment of the inner and outer layers of the headgear with spherical particles on the interfacing surface of the inner layer.

**[0053]** FIG. 14 is a perspective view of the inner layer shown in FIG. 13.

[0054] FIG. 15 is an exploded cross-sectional view of still another embodiment of the inner and outer layers of the headgear with irregular-shaped particles on the interfacing surface of the inner layer.

[0055] FIG. 16 is an exploded cross-sectional view of a final embodiment of the inner and outer layers of the headgear with an intermediate film between the inner and outer layers.

## DETAILED DESCRIPTION OF THE INVENTION INCLUDING A BEST MODE

### NOMENCLATURE

| | |
|---|---|
| **100** | head of person |
| **101** | headgear |
| **103** | forehead area |
| **104** | top of head |
| **105** | temples |
| **106** | ears |
| **107** | back of head |
| **108** | chinstrap |
| **109** | headband embodiment |
| **121** | rivet |
| **200** | head of person |
| **201** | headgear |
| **212** | comfort liner |
| **213** | inner layer |
| **214** | outer layer |
| **215** | interface |
| **300** | head of person |

| | |
|---|---|
| **301** | full coverage embodiment |
| **303** | forehead area |
| **304** | top of the head |
| **312** | comfort liner |
| **313** | inner layer |
| **314** | outer layer |
| **315** | interface |
| **320** | force |
| **321** | rivet |
| **322** | crumpled area of outer layer |
| **323** | areas remote from impact |
| **325** | sliding |
| **328** | edges of headgear |
| **400** | head of person |
| **403** | forehead area |
| **406** | ears |
| **407** | back of head |
| **409** | headband embodiment |
| **413** | inner layer |
| **414** | outer layer |
| **415** | interface |
| **420** | force |
| **421** | rivet |
| **425** | sliding |
| **426** | deformed area |
| **427** | rotation |
| **513** | inner layer |
| **514** | outer layer |
| **515** | interface |
| **530** | nodules |

**531** hair-like projections

**532** spherical particles

**533** non-spherical particles

**534** film

**Construction and Use**

**[0056]** FIGs 1 and 2 are examples of protective headgear **101** and **109**, respectively. FIG. 1 shows the head **100** of a person wearing a unitary piece of headgear **101** that covers the forehead area **103**, the top of the head **104**, the temples **105**, the ears **106**, and the back of the head **107**. As shown in FIG. 1, an optional chinstrap **108** could help secure the headgear **101** to the head **100**. FIG. 2 shows a protective headband **109** that provides a band of coverage from the forehead area **103**, over the temples **105**, to the back of the head **107**.

**[0057]** The purpose of these illustrations is not to exhaust the possible headgear configurations that could employ embodiments of the invention. Rather, the purpose is to show that many different kinds of headgear configurations could embody the invention.

**[0058]** FIG. 3 is a cross-section of the layers of one embodiment of the headgear **201** that could be present in any of the headgear embodiments, including the headgear embodiment **101** of FIG 1 and the headband embodiment **109** of FIG 2. Referring to FIG. 3, the invention can include an optional comfort liner **212** next to the head **200** of the wearer. The comfort liner **212** could be, for example, a lower density, open-cell foam material that easily conforms to the head **200** and provides sweat and heat management characteristics. The comfort liner **212** could also be made up of multiple open-cell foam pads (not shown). Many other kinds of material and configurations of material could be employed in a comfort liner **212**.

**[0059]** The next layer could be the inner layer **213**. The inner layer **213** could consist of padding intended to absorb some of the load of the impact, especially those with a linear

component. It could have plastic or elastic characteristics, depending on the application. Plastic materials have been found to be more suitable for protection from single, high-energy impacts. Materials with plastic characteristics that are commonly used in protective headgear include ones made from polystyrene, polypropylene, or polyurethane. An elastic material should be more suitable for multiple, lower energy impacts where the headgear **101** or **109** needs to be re-used. A common material for such applications would be foams such as cross-linked polyethylene. However, other foams, gels, fluids, or gases sealed in film (not shown) would be suitable for many applications.

**[0060]** The outer layer **214** could also be the exterior layer or the shell. If the outer layer **214** were to act as a shell, it could be made of a rigid or semi-rigid material that distributes the load from an impact over a greater surface area of the inner layer **213**. Suitable rigid or semi-rigid materials include polycarbonate, acrylonitrile-butadiene-Styrene (ABS), or fiberglass reinforced plastic (FRP). Materials suitable for forming a less rigid outer layer **214** include specifically, but not exclusively, foam, fabric or impregnated fabric.

**[0061]** The outer layer **214** (especially for linear impacts) may perform more of a load distribution function while the inner layer **213** may perform more of a load absorption function. These functional roles, however, are not essential to the invention.. For example, it may be desirable in certain circumstances to have both the inner layer **213** and the outer layer **214** perform a load distribution function with a third layer (not shown) performing a load absorption function. In such an instance, both the inner layer **213** and outer layer **214** could be made of the same rigid or semi-rigid materials described above. Alternatively, both the inner layer **213** and outer layer **214** could perform load absorption functions. In this case both layers **213** and **214** could be made of the materials intended for energy absorption described above.

**[0062]** The inner layer **213** and outer layer **214** need not be innermost or outermost layer respectively. The inner layer **213** and outer layer **214** could be the only two layers in the headgear **201**, or they could be two of many layers. Additionally, the inner layer **213** and outer layer **214**may be composed of sub-layers. The descriptive terms inner and outer simply establish

the relationship between two layers, with the inner layer **213** positioned closer to the head **100**, **200**, **300**, **400** than the outer layer **214**.

**[0063]** Referring to FIG. 3, the inner layer **213** cooperates with the outer layer **214** at the layer interface **215** defined by the exterior surface (unnumbered) of the inner layer **213** and the interior surface (unnumbered) of the outer layer **214**.

**[0064]** At least at certain points at the interface **215**, the inner layer **213** and outer layer **214** are not connected to each other. Thus, when the exterior surface (unnumbered) of the outer layer **214** encounters an oblique force, such as forces **320** and **420** shown in FIGs 4-8, the exterior surface (unnumbered) of the inner layer **213** and the interior surface (unnumbered) of the outer layer **214** will slide in relation to one another. At other points the inner layer **213** and outer layer **214** are connected. These connection points are generically referred to herein as anchor points.

**[0065]** FIG 4 depicts one embodiment of the invention subjected to an oblique force **320** having an angular vector (not separately shown). The headgear **301** in this embodiment covers the top of the head **304** and could be the same as the one shown in FIG. 1. In addition, the embodiment of the headgear **301** shown in FIG. 4 could have the same layers as those depicted in FIG. 3, (*i.e.*, an outer layer **314**, an inner layer **313**, an interface **315**, and a comfort liner **312**). The headgear **301** of the embodiment shown in FIG. 4 includes a rivet **321** attaching the inner layer **313** and the outer layer **314** to each other at a single anchor point. Many other kinds of fasteners suitable for use in forming an anchor point are known to those skilled in the art, including specifically but not exclusively, sewn seams, adhesives and heat welding.

**[0066]** The location of the anchor points could be varied. By way of example, FIG. 2 shows an alternative location for the anchor points wherein rivets **121** are located on opposite the sides of the headgear **109** just above the ears **106**. Other anchor point locations might also be desirable.

[0067] As shown in FIG. 4, the outer layer **314** may be formed of a material which is relatively non-rigid and therefore could be deformed when subjected to an oblique force **320** as evidenced by the crumpled area **322** over the forehead **303** of a wearer. Crumpling of the outer layer **314** is particularly desired when the inner layer **313** and outer layer **314** are anchored with a fastener, such as rivet **321**, which is not elastic. Such crumpling allows the interior surface (unnumbered) of the outer layer **314** to slide **325** in relation to the exterior surface (unnumbered) of the inner layer **313** even though the fastener (*e.g.*, rivet **321**) rigidly attaches the inner layer **313** and the outer layer **314** at the anchor points.

[0068] FIG. 5 shows an embodiment of headgear **301** similar to the headgear **301** shown in FIG. 4 subjected to an oblique force **320**. The outer layer **314** on the headgear **301** depicted in FIG. 5 is more rigid than the outer layer **314** on the headgear **301** depicted in FIG. 4. Hence, the outer layer **314** does not crumple when subjected to an oblique force **320**. Rather, an elastic rivet **321** is employed at the anchor point, allowing the rivet **321** to stretch and thereby allow the interior surface (unnumbered) of the outer layer **314** to slide **325** in relation to the exterior surface (unnumbered) of the inner layer **313** proximate the point of impact (unnumbered), even though the outer layer **314** is not appreciably deformed by the oblique force **320**. The outer layer **314** may be lifted off the inner layer **313** at areas remote from the point of impact, such as represented by arrows **323** in FIG. 5.

[0069] FIG. 7 shows another embodiment of the invention in the form of a headband **409**. The headband **409** is represented as subjected to an oblique force **420**. In this embodiment of the invention, the inner layer **413** and outer layer **414** are attached to each other at two laterally aligned anchor points by rivets **421** positioned just above each ear **406**. The outer layer **414** depicted in this embodiment is constructed of a relatively non-rigid material which will deform when subjected to an oblique force **420** as evidenced by the deformed area **426**. The inner layer **413** and outer layer **414** may be securely attached to one another, such as by an adhesive (not shown); over that portion (unnumbered) of the headband **409** covering the back **407** of the head **400** to ensure that deformation occurs about the anchor points. Deformation about the anchor points causes the interior surface (unnumbered) of the outer layer **414** to slide **425** in relation to

the exterior surface (unnumbered) of the inner layer **313** only on that portion of the headband **409** covering the forehead area **403**.

**[0070]** Referring to FIG. 8, the headband **409** may alternatively be constructed without attaching the inner layer **413** and the outer layer **414** at the back **407** of the head **400**. Such an embodiment permits the entire outer layer **414** to rotate **427** as a unit about the rivets **421**, resulting in sliding **425** of the front (unnumbered) and back (unnumbered) portions the interior surface (unnumbered) of the outer layer **415** over the exterior surface (unnumbered) of the inner layer **413**. The amount of rotation **427** can be controlled by controlling the tightness of the rivets **421**.

**[0071]** Referring to FIG. 6, at least a portion of the interface **315** may optionally be sealed, such as by fusing the inner layer **313** and the outer layer **314** along the edges **328** and the interface **315** filled with a flowable material (unnumbered) such as solid particulates, liquid, gel or gas. When such a "filled" headgear **301** is subjected to an oblique force **320**, the interior surface (unnumbered) of the outer layer **314** will slide in relation to the exterior surface (unnumbered) of the inner layer **313** by deformation of the inner layer **313** and/or the outer layer **314**, thereby causing the fluid to flow within the sealed interface **315** such as represented in FIG. 6. The thickness of the filled interface **315** may be selected as necessary to achieve the desired effect, with a thickness of just a few thousandths of an inch suitable for many applications. The flow properties of the fluid retained within the sealed interface **315** will affect the ease or difficulty with which the outer layer **314** will slide in relation to the exterior surface (unnumbered) of the inner layer **313**. For example, a high viscosity fluid might inhibit sliding, while a low viscosity fluid might facilitate sliding.

**[0072]** Particles (not shown) may optionally be suspended in the fluid retained within the sealed interface **315** to achieve a desired flow characteristic. When particles are incorporated into the fluid, the fluid preferably has a higher viscosity for purposes of facilitating long-term suspension of the particles in the fluid.

[0073] The ease or difficulty with which the interior surface (unnumbered) of the outer layer **214, 314, 414, 514** slides relative to the exterior surface (unnumbered) of the inner layer **213, 313, 413, 513** (hereinafter "slide control") can be controlled in any number of ways. One variable which can be altered to effect slide control is the rigidity of the inner layer **213, 313, 413, 513** and/or the outer layer **214, 314, 414, 514**. Another is the elasticity of the mechanism attaching the layers at each anchor point.

[0074] Another variable which can be altered to effect slide control is the frictional properties at the interface **215, 315, 415, 515** between the inner layer **213, 313, 413, 513** and/or the outer layer **214, 314, 414, 514**. Several specific means for effecting a specific frictional property at the interface **215, 315, 415, 515** are shown in FIGs 9-16. FIGs 9 and 10 show nodules **530** on the interior surface (unnumbered) of the outer layer **514** and the exterior surface (unnumbered) of the inner layer **513**. FIGs 11 and 12 show hair-like projections **531** (*e.g.*, felt) on the interior surface (unnumbered) of the outer layer **514** and the exterior surface (unnumbered) of the inner layer **513**. FIGs 13 and 14 show spherical particles **532** on the exterior surface (unnumbered) of the inner layer **513**. FIG. 15 shows irregular shaped particles **533** on the exterior surface (unnumbered) of the inner layer **513**. FIG. 16 shows an intermediate film **534** positioned between the interior surface (unnumbered) of the outer layer **514** and the exterior surface (unnumbered) of the inner layer **513**. Other embodiments would also be known to those skilled in the art.

[0075] An additional advantage recognized with the hair-like projections **531** and the nodules **530** is the ability of such features to absorb an oblique force by toppling or collapsing when subjected to such a force.

[0076] The present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as fairly set out in the claims arising from this application. For example, while suitable sizes, materials, fasteners, and the like have been disclosed in the above discussion, it should be appreciated that these are provided by way of example and not of limitation as a number of other sizes, materials,

fasteners, and so forth may be used without departing from the invention. Various modifications as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art to which the present invention is directed upon review of the present specifications. The claims which arise from this application are intended to cover such modifications and structures.